



Ford Inova Fairfax Hospital CIREN Team



Ford Motor Company

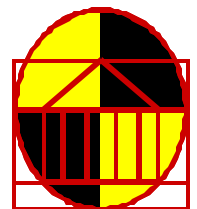
**Inova
Regional
Trauma
Center**



**DEPARTMENT OF MECHANICAL
AND AEROSPACE ENGINEERING**



**Automobile
Safety
Laboratory**





Physiologic and Biomechanical Considerations



Introduction

- The elderly (age > 65) comprise 12% of the population
- Elderly trauma patients account for 25% of injury fatalities per year
- 33% of health care resources are spent on geriatric trauma care
- Urgent need to focus healthcare resources
(Bulger, Arneson, Mock, & Jurkovich, 2000)

The Elderly Population

- Census data suggests that the elderly population will expand by 50% by 2050
- The annual occurrence of traumatic injuries in the elder cohort is reported to be as high as 29%. *(Marciani, 1999)*
- Geriatric trauma patients represent the most rapidly growing trauma population

Known Facts

- Elderly patients are almost five times more likely to die after trauma than similarly injured younger patients
(Perdue, Watts, Kaufmann & Trask, 1998)w
- Increased mortality seen in elderly patients may be a reflection of diminished physiologic reserve associated with the aging process

- Defining “elderly” is difficult, since some 70 year olds are physiologically younger than some 55 year olds!
- The decrease in the ability of individuals to withstand the stress of trauma is related to the normal biologic degenerative process, pre-existing illness and the overall well-being of the trauma victim

Reality Check

- Much is assumed about the elderly trauma patient, but little is known:
The literature would lead you to believe that the elderly as a group have significantly impaired physiologic function
- Actual data would suggest that with invasive monitoring and aggressive management, outcomes for the elderly can be significantly improved
(Scalea et al J Trauma 1990, 30:129)

Initial Trauma Care

- Although age alone is not a criterion for trauma team activation, the elderly as a group are especially susceptible to serious injuries and require immediate, high-level care to avoid poor outcomes

- **A** - cervical spine protection may be difficult because of osteoporosis, particularly during endotracheal intubation
- **B** - mechanical ventilation should be started early to support ventilation
- **C** - prolonged hypovolemia is worse than fluid overload

Blunt Trauma Resuscitation

- Elderly patients have initially depressed cardiac index but can generate a hyperdynamic response
- Ultimate outcome is poorer than in a younger cohort with equivalent injury
(McKinley, Marvin, Cocanour, Marquez, Ware & Moore, 2000)

The Bottom Line

- The normal processes of aging may be a contributing factor because of:
 - sensory changes
 - slowing of reflexes
 - musculoskeletal changes
- The elderly are not just older versions of young people; they require care directed at their specific needs

Special Considerations

Neurologic Changes

- Decreased cerebral blood flow
- Brain atrophy
- Increased space in the cranial vault
- Alterations in senses - smell, vision, hearing, touch
- Short-term memory changes

Special Considerations:

Cardiovascular Changes

- Vasculature becomes less elastic & sympathetic response is slow
- Compensatory mechanisms tend to be less effective
- Decrease in cardiac contractility causes lower stroke volume and cardiac output

Special Considerations:

Pulmonary Changes

- Decrease in lung field size and compliance
- Blood flow to the lung is decreased
- Vital capacity is diminished and gas exchange impaired
- Decreased gag and cough reflexes increase risk of aspiration and pneumonia
- Increased chest wall stiffness

Frequent Respiratory Complications

- Pneumonia
- Pulmonary Effusion
- ARDS
- Lobar Collapse

(Bulger, Arneson, Mock & Jurkovich, 2000)

Special Considerations:

Hepatic Changes

- Decreased total liver blood flow may contribute to adverse drug reactions
- Polypharmacy
- Compromised liver function may increase risk of coagulopathy

Special Considerations:

Immune System Changes

- Decreased antibody production in response to antigens
- Decreased inflammatory response
- Increased multisystem failure and sepsis from infectious complications

Musculoskeletal Changes

- Osteoporotic changes
- Joint stiffness secondary to arthritic and other inflammatory conditions
- Bone density and bone mass loss
- Joints and ligaments are less elastic
- Cervical degenerative changes



Trauma Pearls

- Consider dual diagnoses:
 - “Did the MI occur and cause the trauma?”
 - “Did low cerebral bloodflow contribute to the LOC change and be the underlying cause of the trauma?”
- The interval between early warning and “crashing and burning” is abbreviated in the elderly
- Not all older people are confused and disoriented!

Trauma Pearls (cont'd)

- ✓ Always consider co-morbid and pre-existing conditions:
 - Hypertension
 - Coronary artery disease
 - Dysrhythmias
 - Chronic obstructive pulmonary disease
 - Diabetes mellitus

(Ferrera, Bartfield & D'Andrea, 2000)

Outcomes Research

- Preexisting comorbid conditions did not play a significant role in the ultimate outcomes of geriatric trauma patients
- Severity of injury is the leading determinant of death

(Ferrera, Bartfield & D'Andrea, 2000)

Predictors of Morbidity & Mortality

- ISS predicted ARDS, pneumonia, sepsis & GI complications
- Mortality correlates closely with ISS and is influenced by blood and fluid requirements and by GSC score

(Tornetta, Mostafavi, Riina, et. al 1999)

Long- Term Survival

- Following acute injury, mortality seems to be mediated through a decline in function resulting from the injury
- Strategies to return the elderly patient to preinjury functional status are crucial

(McGwin, Melton, May & Rue, 2000)

Conclusions

- There is insufficient research on the association of trauma, pre-injury comorbidities and the aging process
- The collaboration of clinicians and engineers in reducing the severity of crash-related geriatric trauma continues to be an important approach for advancing geriatric trauma care



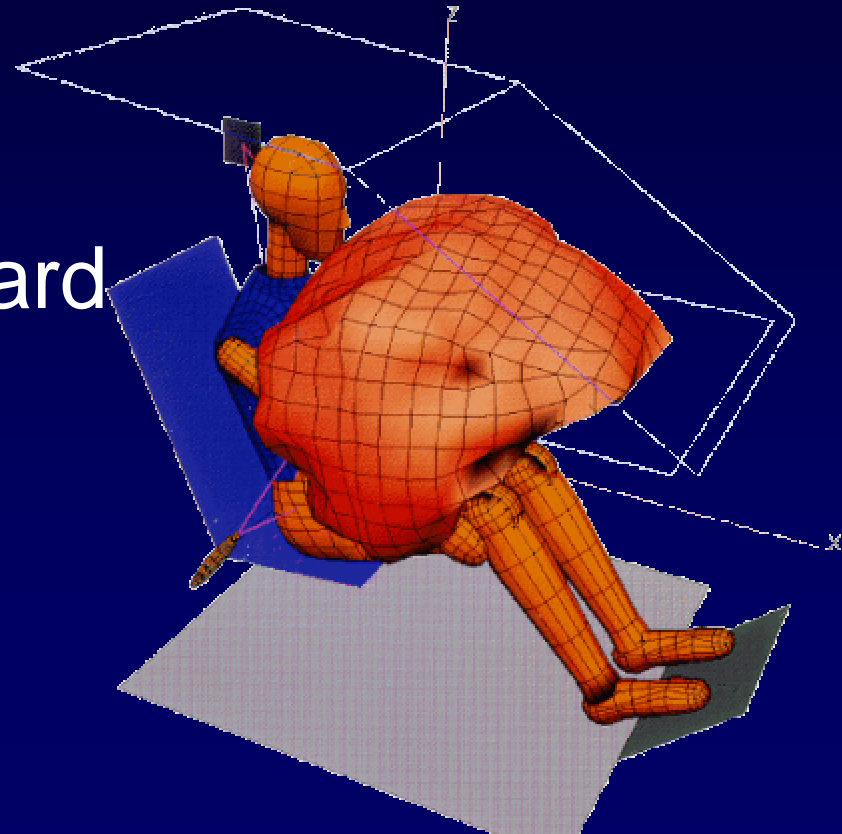
Biomechanical Considerations

Summary – Aging Issues

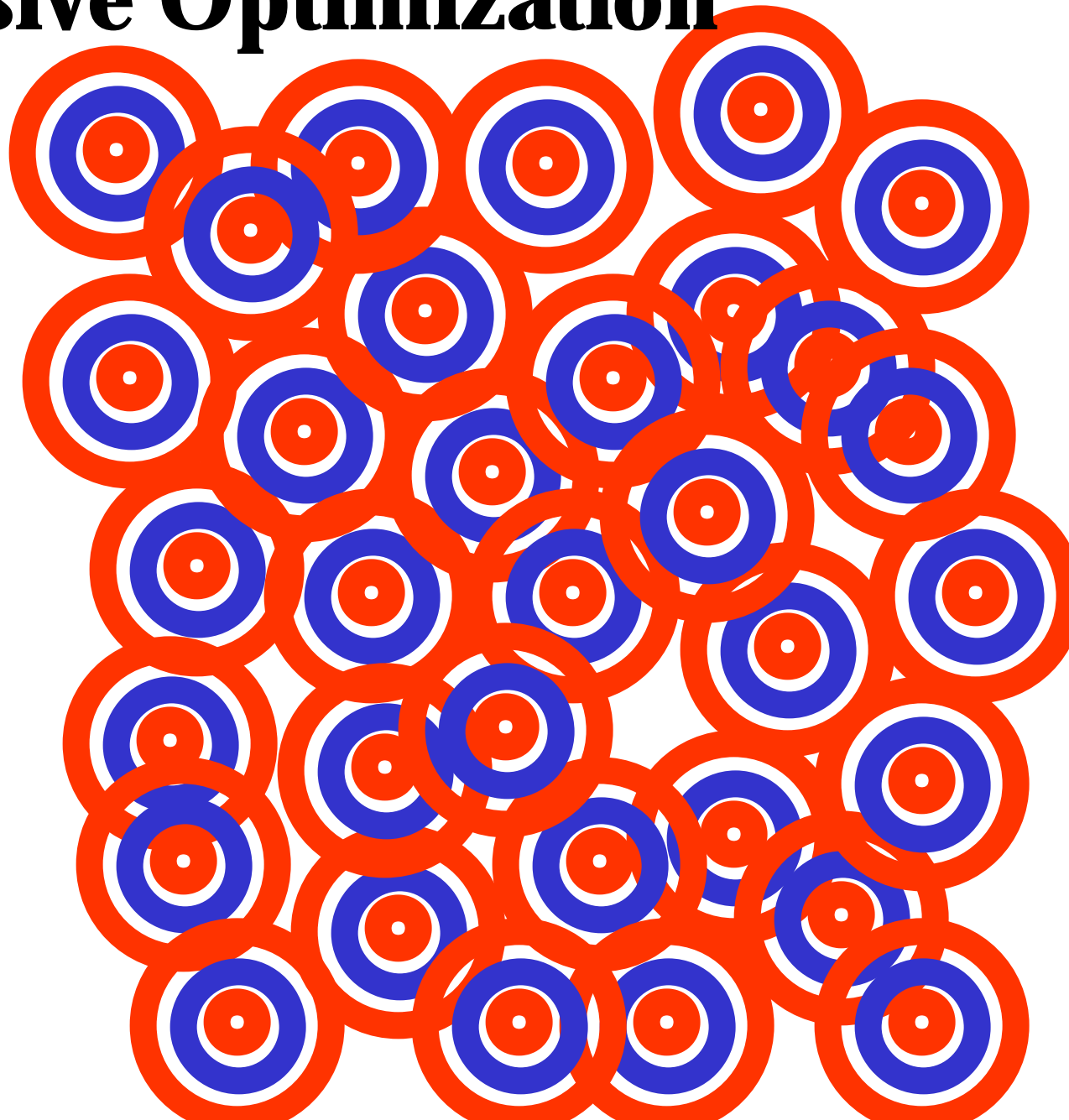
- Collisions
 - More lateral, lower speed
- People
 - Injury tolerance ↓
 - Female/Male ratio ↑ (100/39 by age 85)
 - Variability in injury tolerance ↑
(older population unique for its heterogeneity)
- Vehicle
 - Larger
- Behavior
 - Day (off peak), short trips

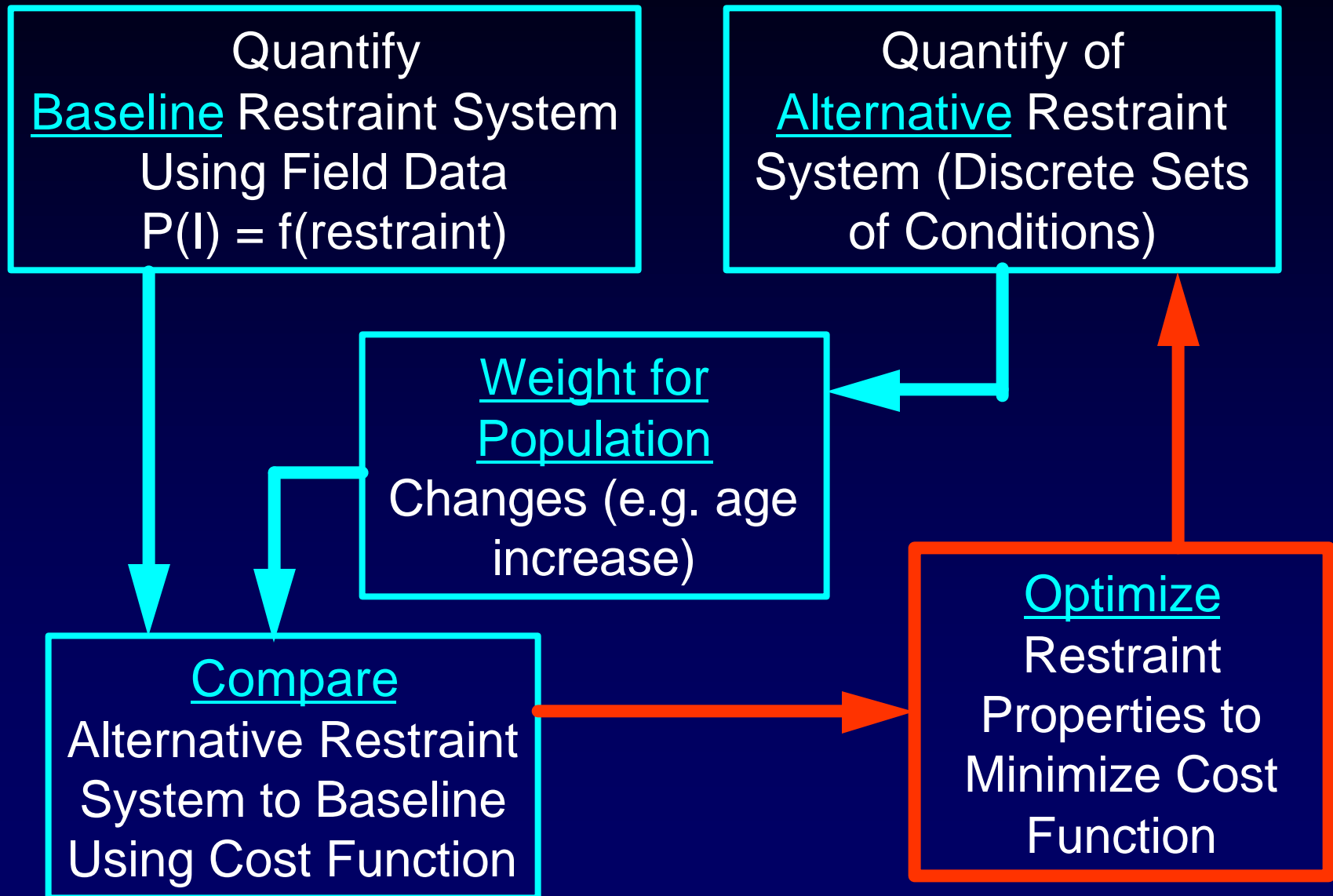
Restraint Considerations for an Older Occupant

- Minimize Forces Applied to Body
- Minimize Body Deformations
- Minimize Local Forces
- Control Kinematics to Avoid Contacts with Hard Vehicle Components
- Optimization

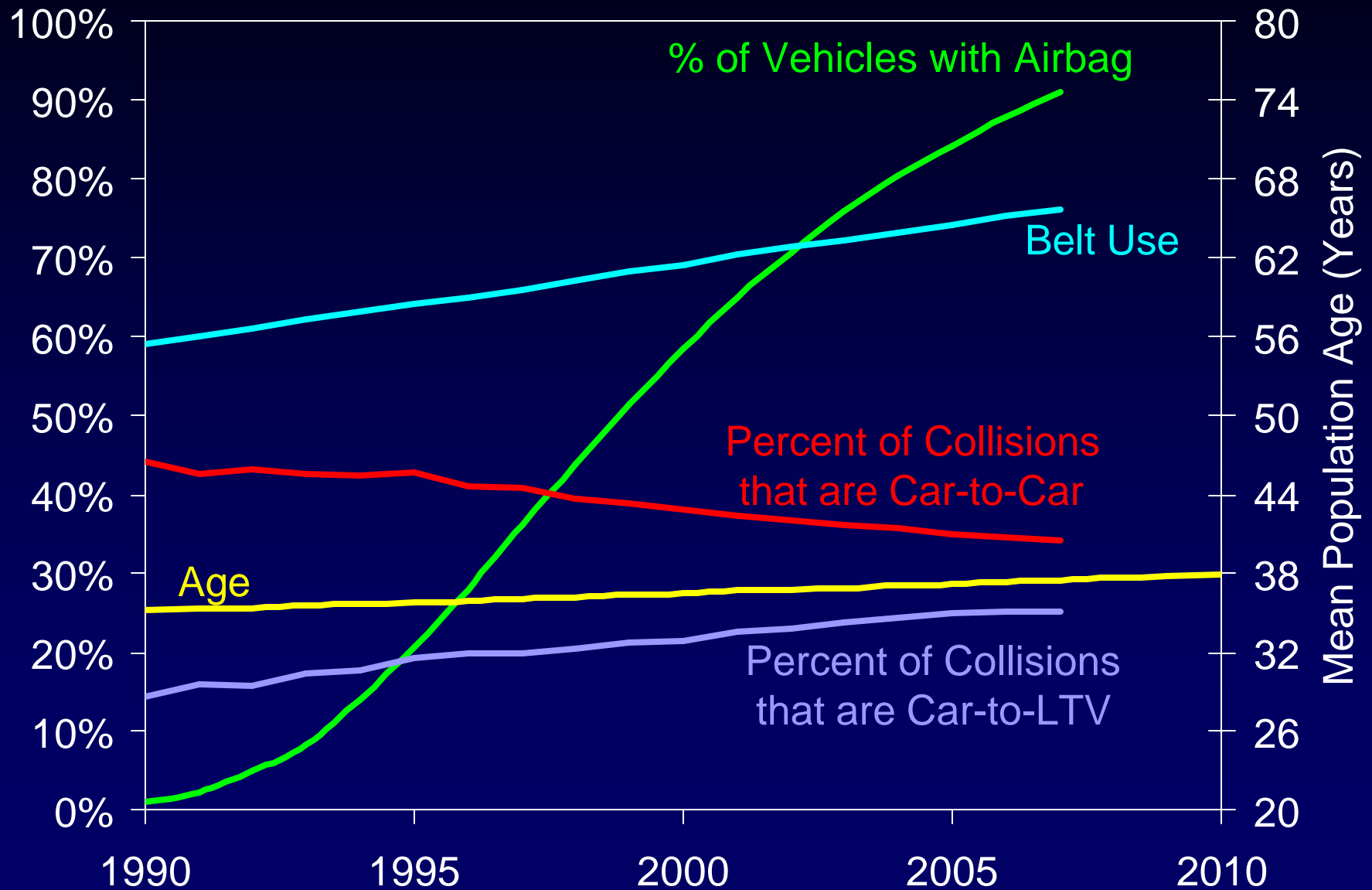


Passive Optimization

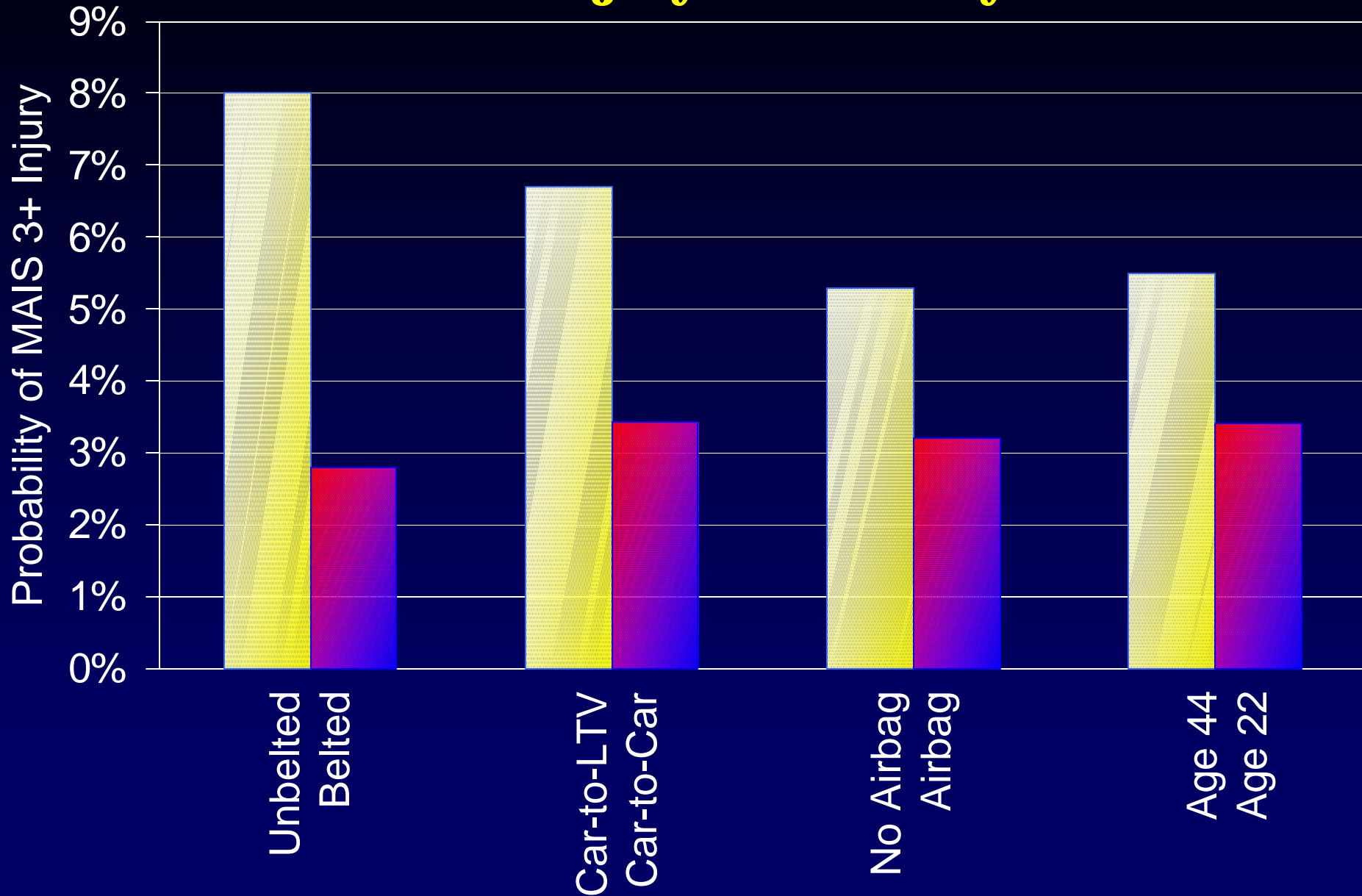




Projections of Several Parameters that Affect Injury Probability

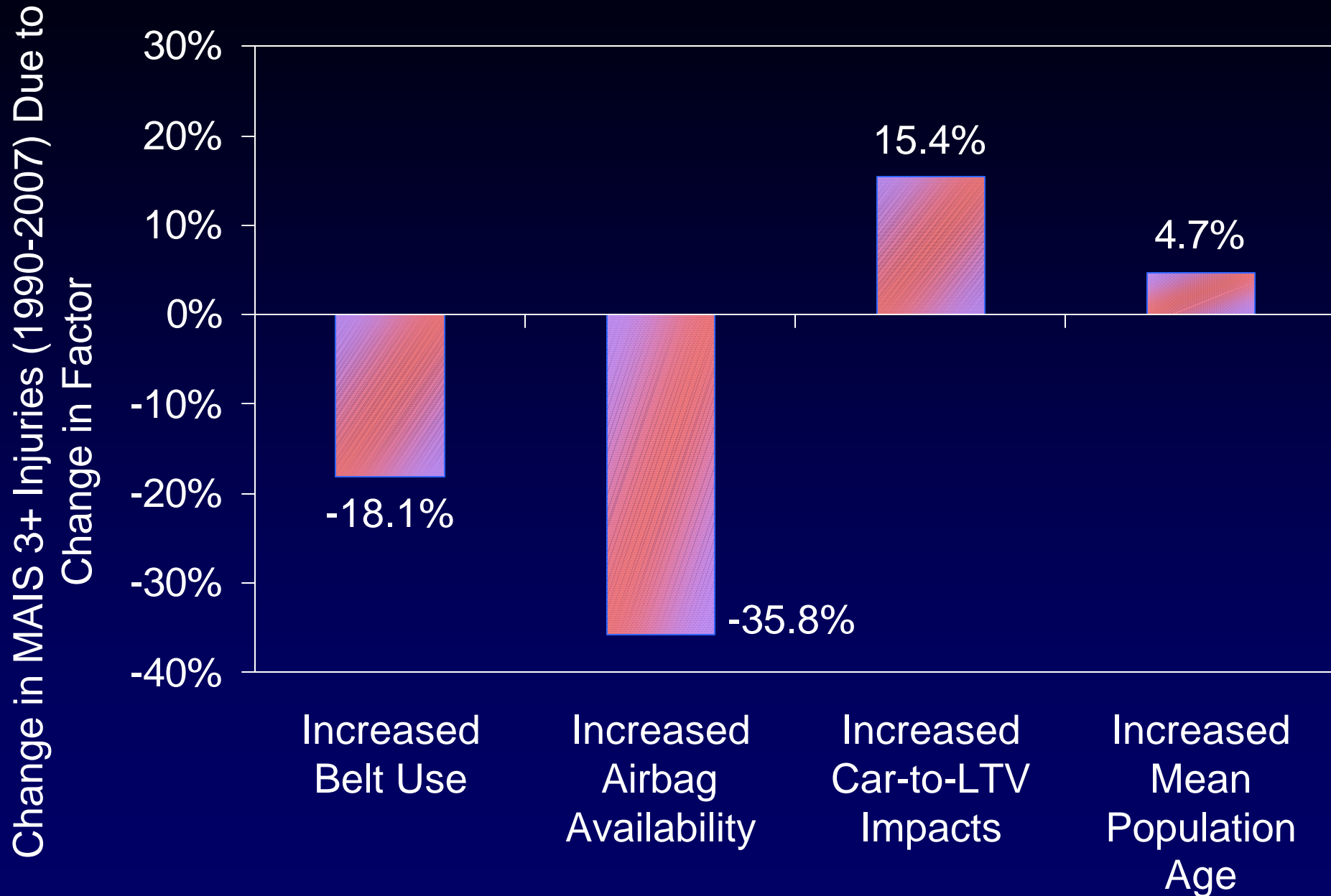


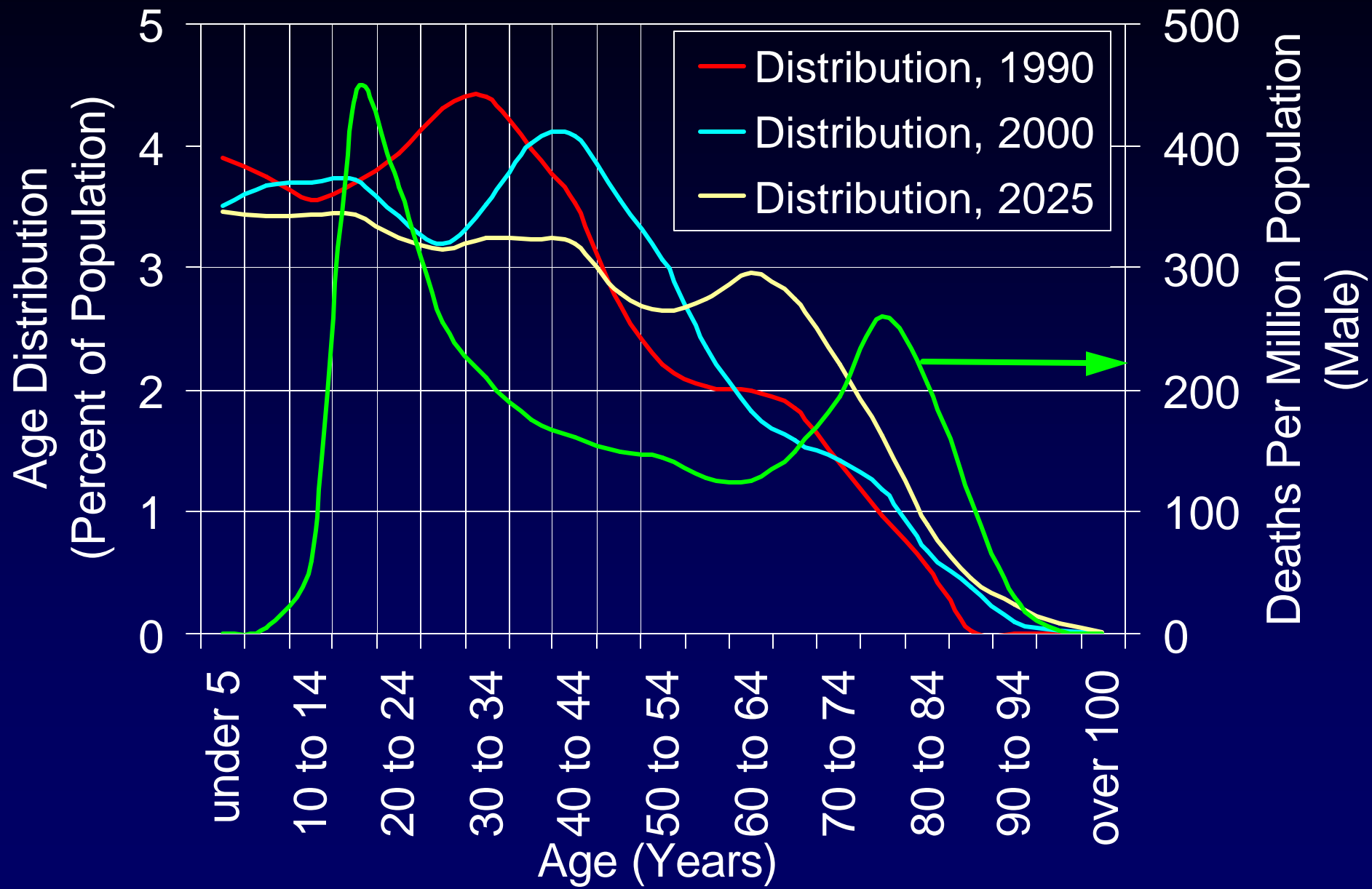
Influence of Several Factors on Driver Injury Probability



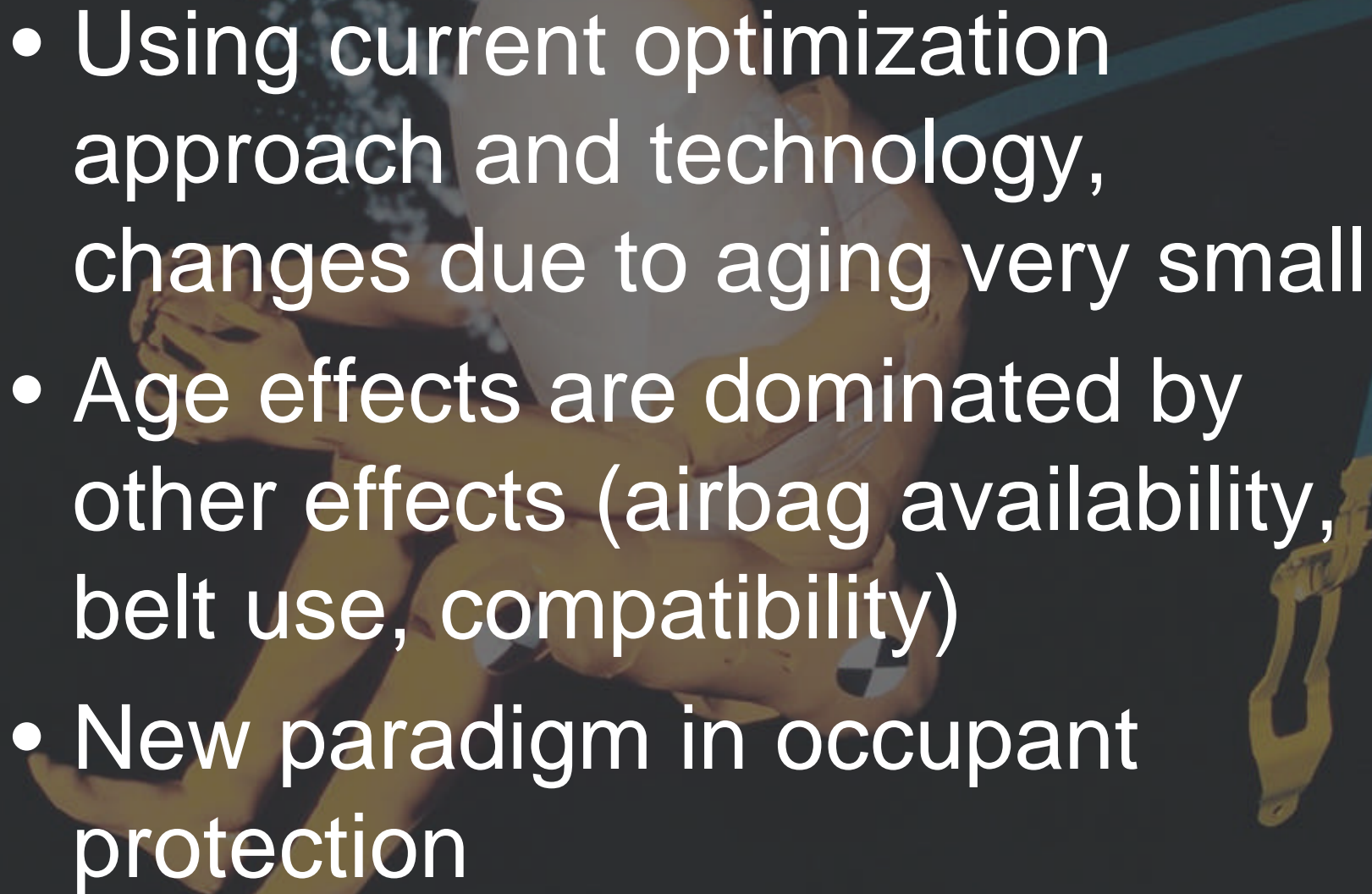
MAIS 3+ Injuries (1990-2007)

Change in MAIS 3+ Injuries (1990-2007)

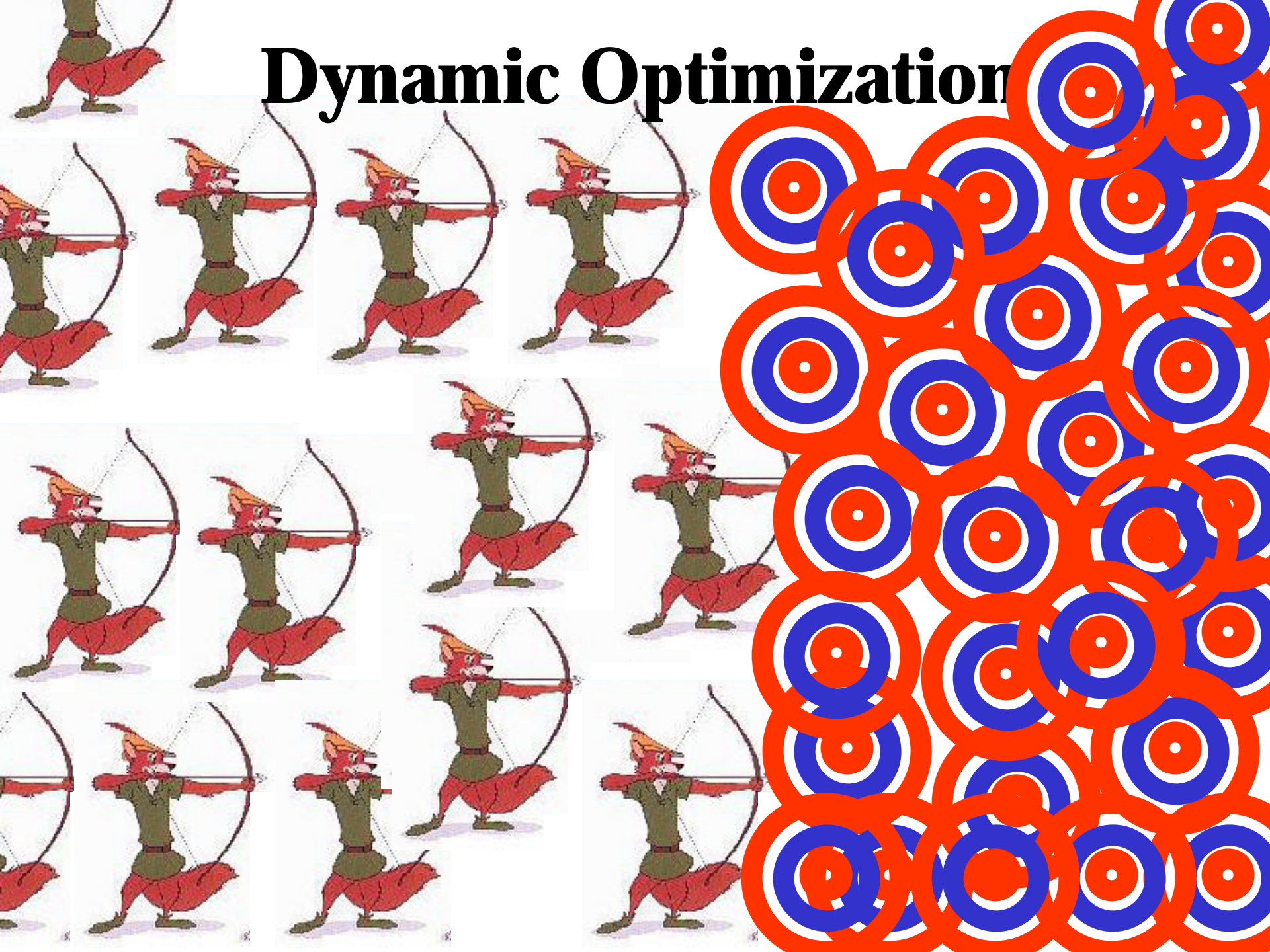




Passive Restraint Optimization

- Using current optimization approach and technology, changes due to aging very small
 - Age effects are dominated by other effects (airbag availability, belt use, compatibility)
 - New paradigm in occupant protection
- 
- A crash test dummy is shown seated in a car seat, wearing a seatbelt. The dummy is positioned in a way that suggests a crash test scenario. The background is dark, and the seatbelt is a light blue color. The dummy's head is tilted back, and its arms are resting on its knees. The seatbelt buckle is visible on the right side of the image.

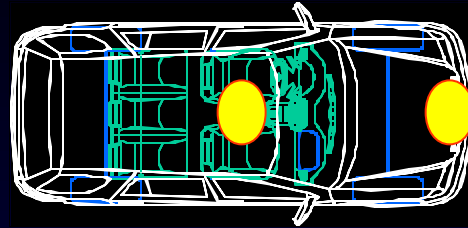
Dynamic Optimization



DYNAMIC OPTIMIZATION

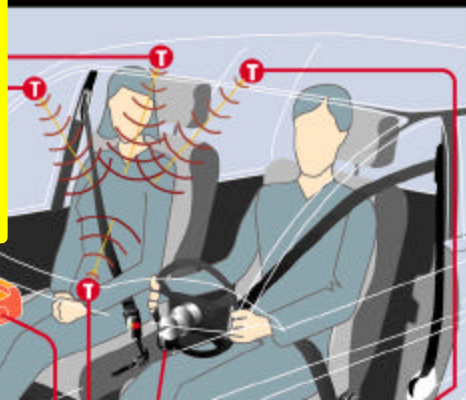
VEHICLE SENSOR

Impact
severity,
Angle



OCCUPANT SENSOR

Condition
(Age, Gender,
Mass, Size),
Position, Belt
Use



OPTIMIZATION
ALGORITHM

RESTRAINT PARAMETERS

SPECIFIC TO
OCCUPANT
AND
COLLISION





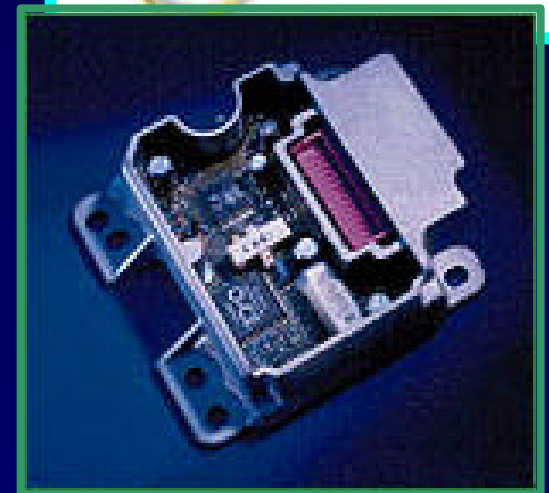
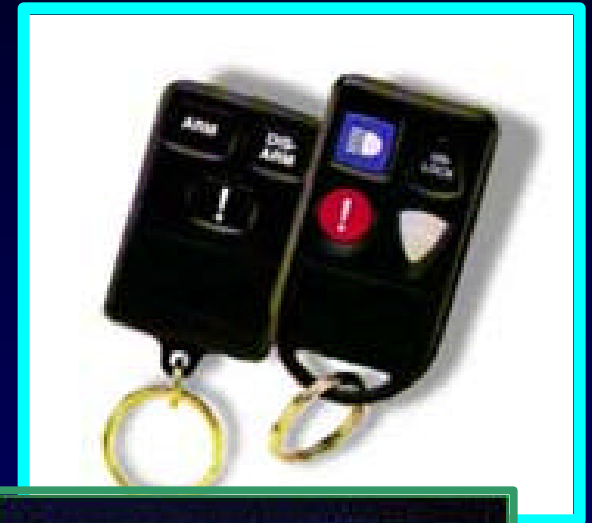
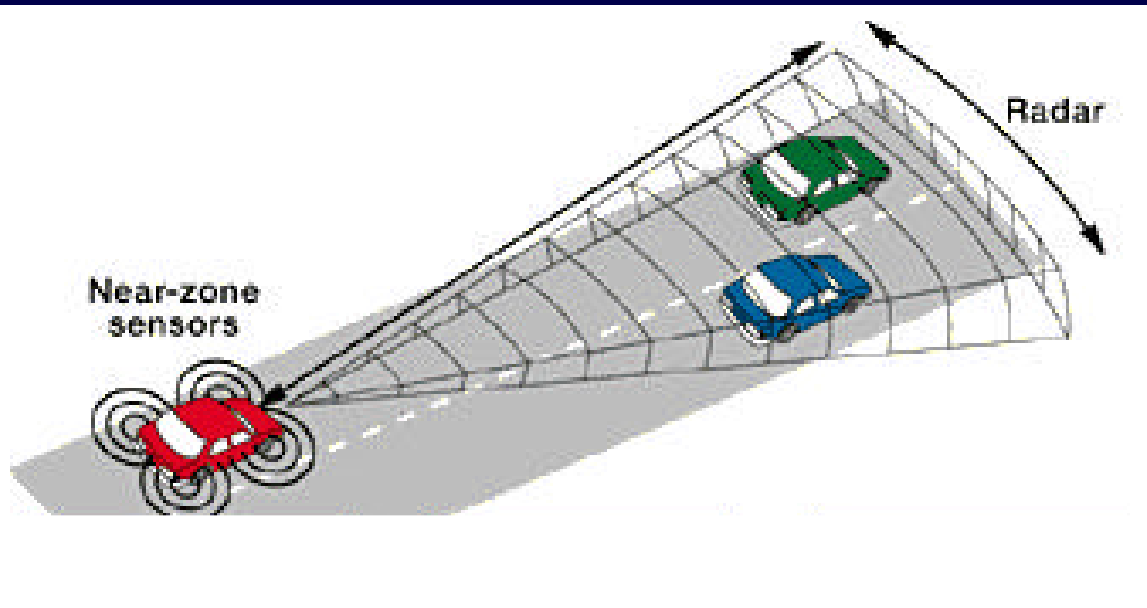
~~Opportunities Challenges of Dynamic Optimization~~

- SENSING
- ADJUSTING RESTRAINT
PARAMETERS
- INTERPRETING SENSED
INFORMATION

Opportunities ~~Challenges~~ of Dynamic Optimization

- SENSING
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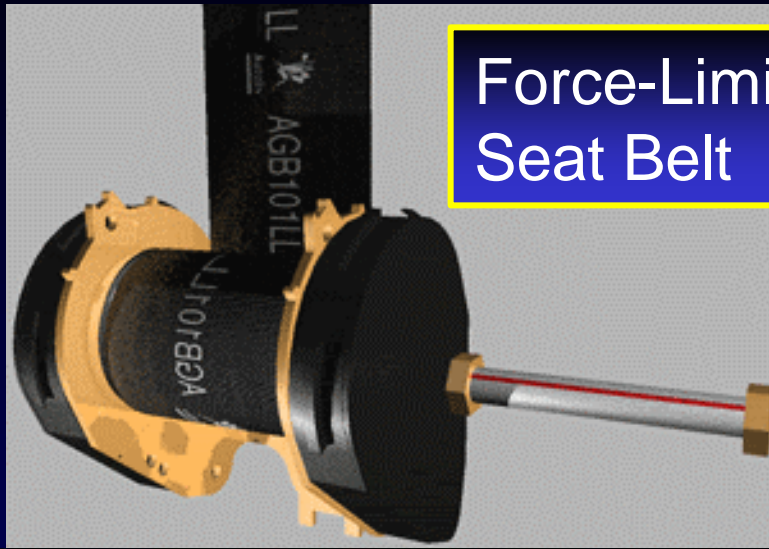
- **Keyless Entry Transmitter** Programmed with Information About Age, Gender, Size
- **Interior Sensors** Determine Position, Belt Use, Physiology
- **Vehicle Sensors** Provide Information about Crash



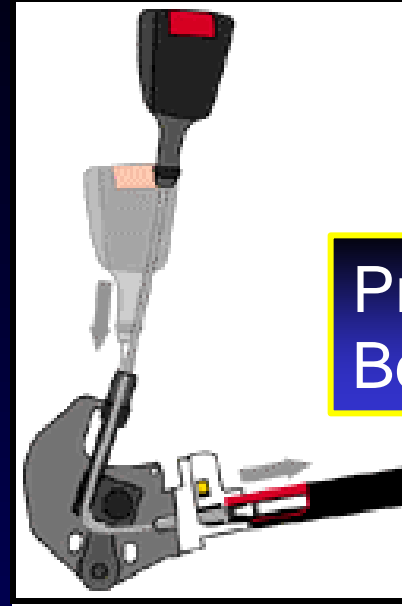
Opportunities ~~Challenges~~ of Dynamic Optimization

- SENSING
- ADJUSTING RESTRAINT
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INFORMATION

ADJUSTING RESTRAINT PARAMETERS



Force-Limiting
Seat Belt



Pretensioning
Belt System



Multi-Stage
Airbag Inflation



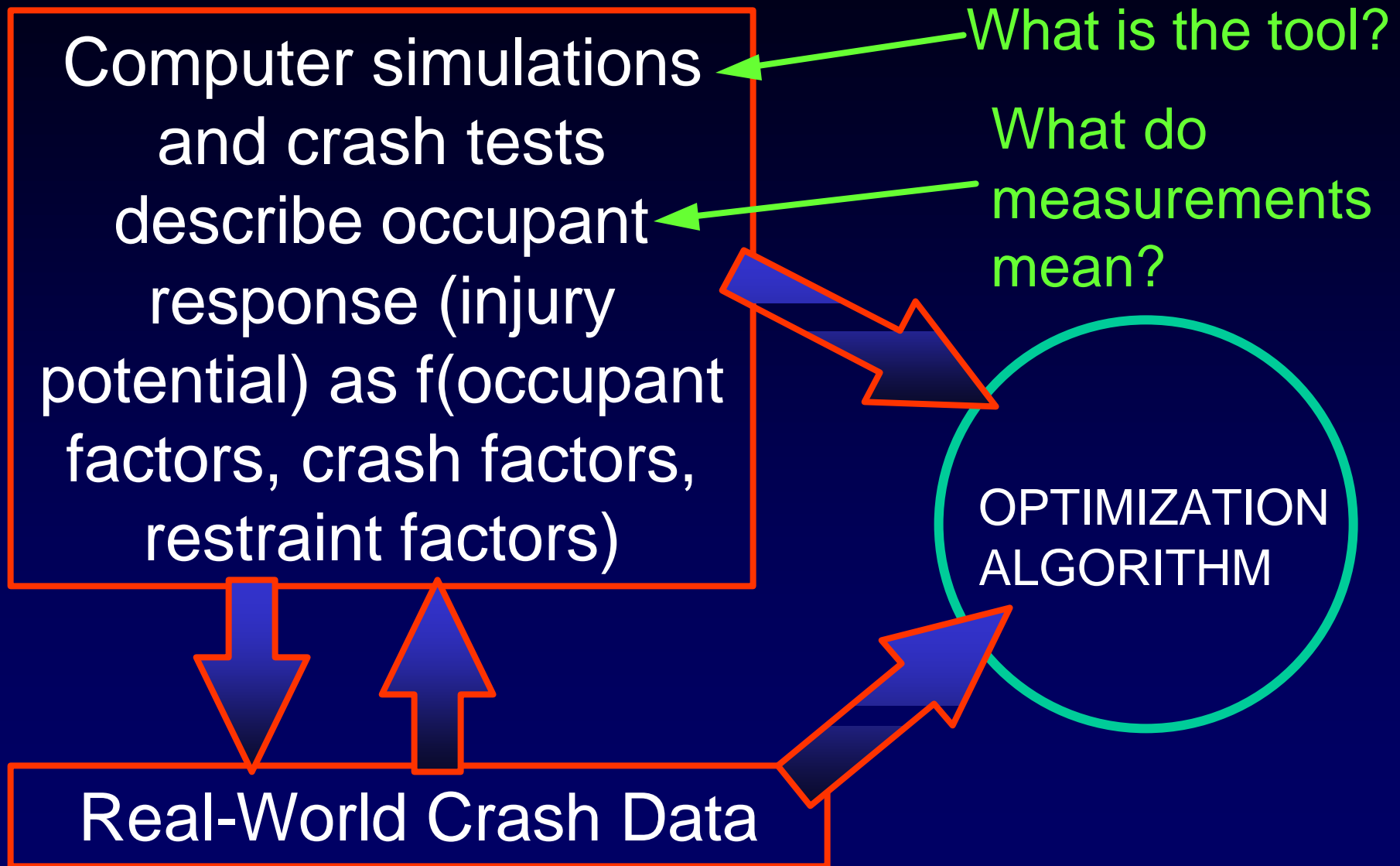
Other Airbags (Load Sharing)

A crash test dummy is shown in a dynamic pose, possibly during a simulation or experiment. The dummy is white and yellow, with a blue strap attached to its back. The background is dark and textured, suggesting a laboratory or simulation environment. The title text is overlaid on the top half of the image.

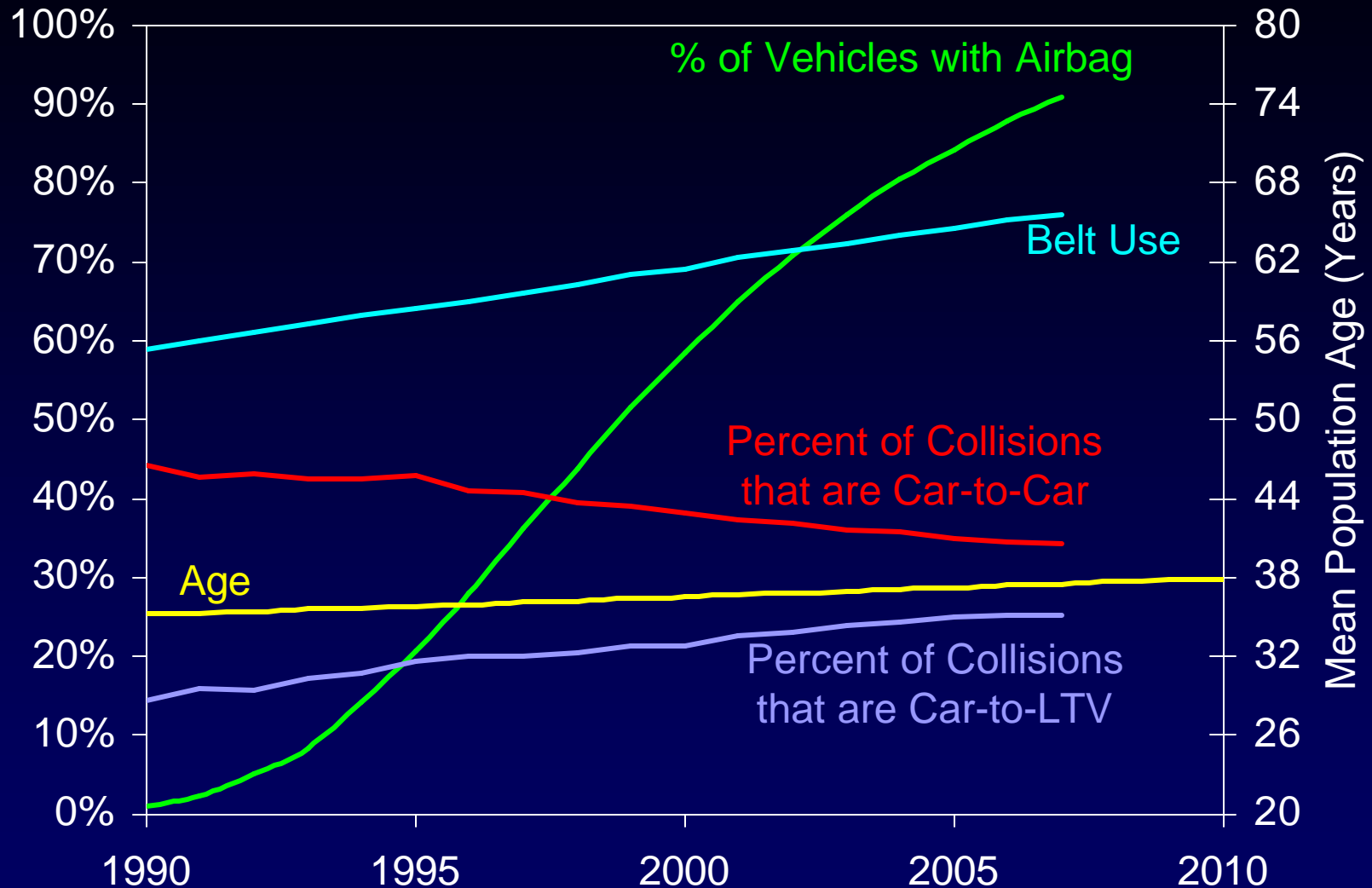
Opportunities ~~Challenges~~ of Dynamic Optimization

- SENSING
- ADJUSTING RESTRAINT
PARAMETERS
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INFORMATION

DYNAMIC OPTIMIZATION



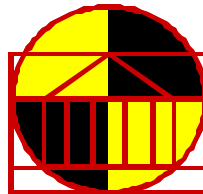
Parameters that Affect Injury Probability



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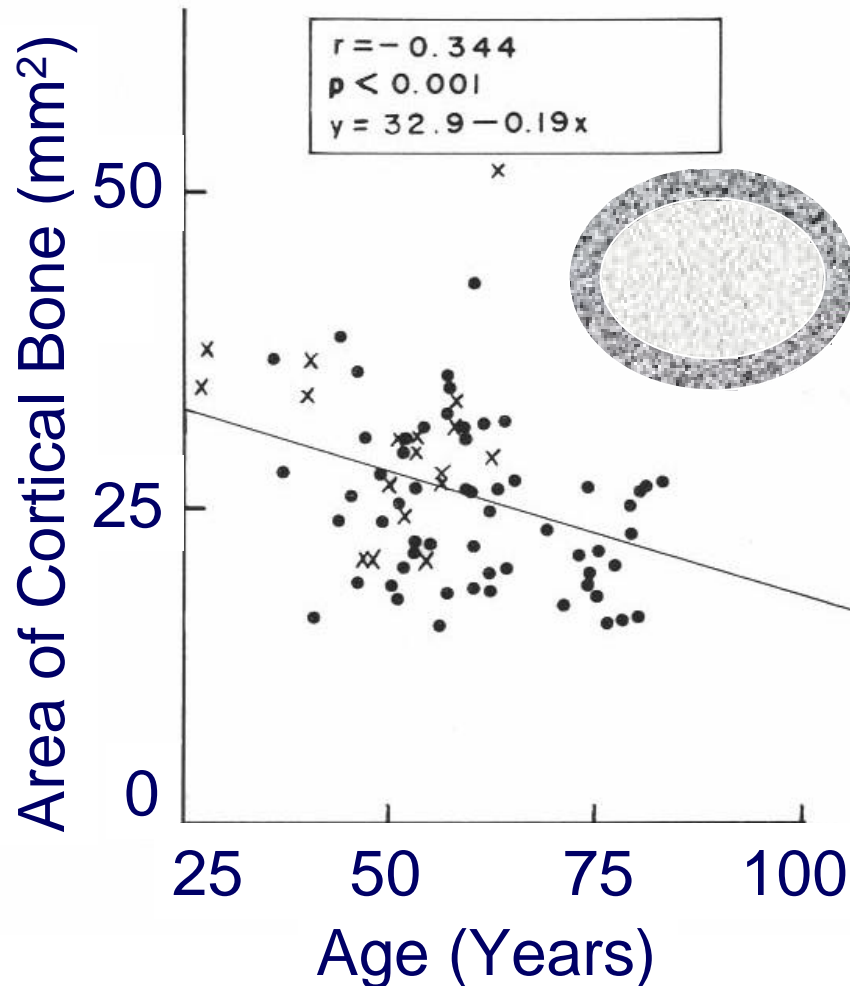
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Virginia

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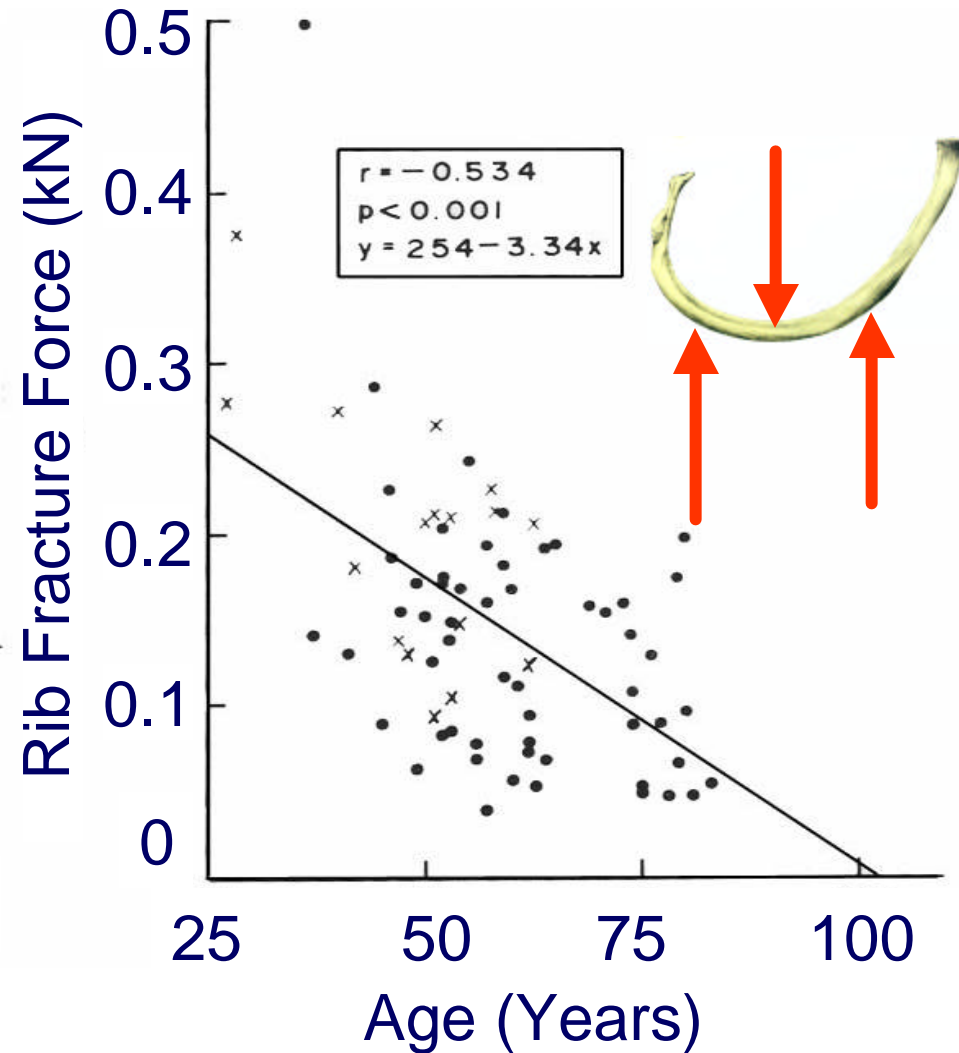
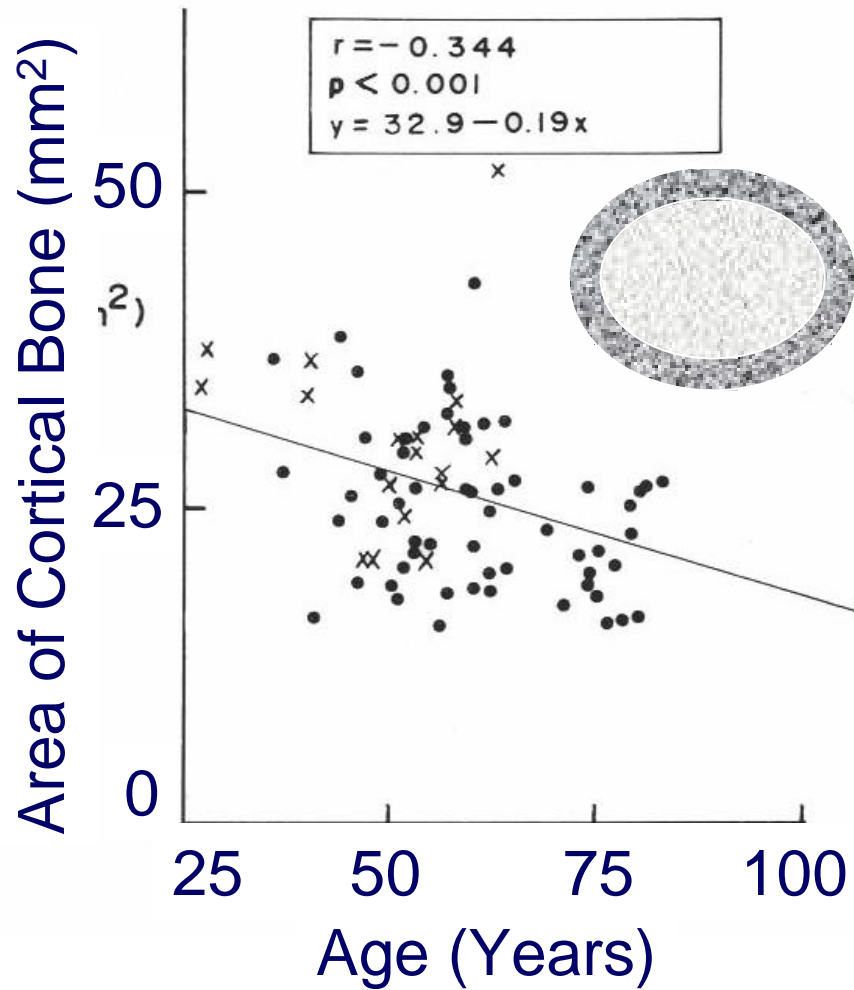
What is the Tool?

Can A Dummy Represent all Adult Ages?

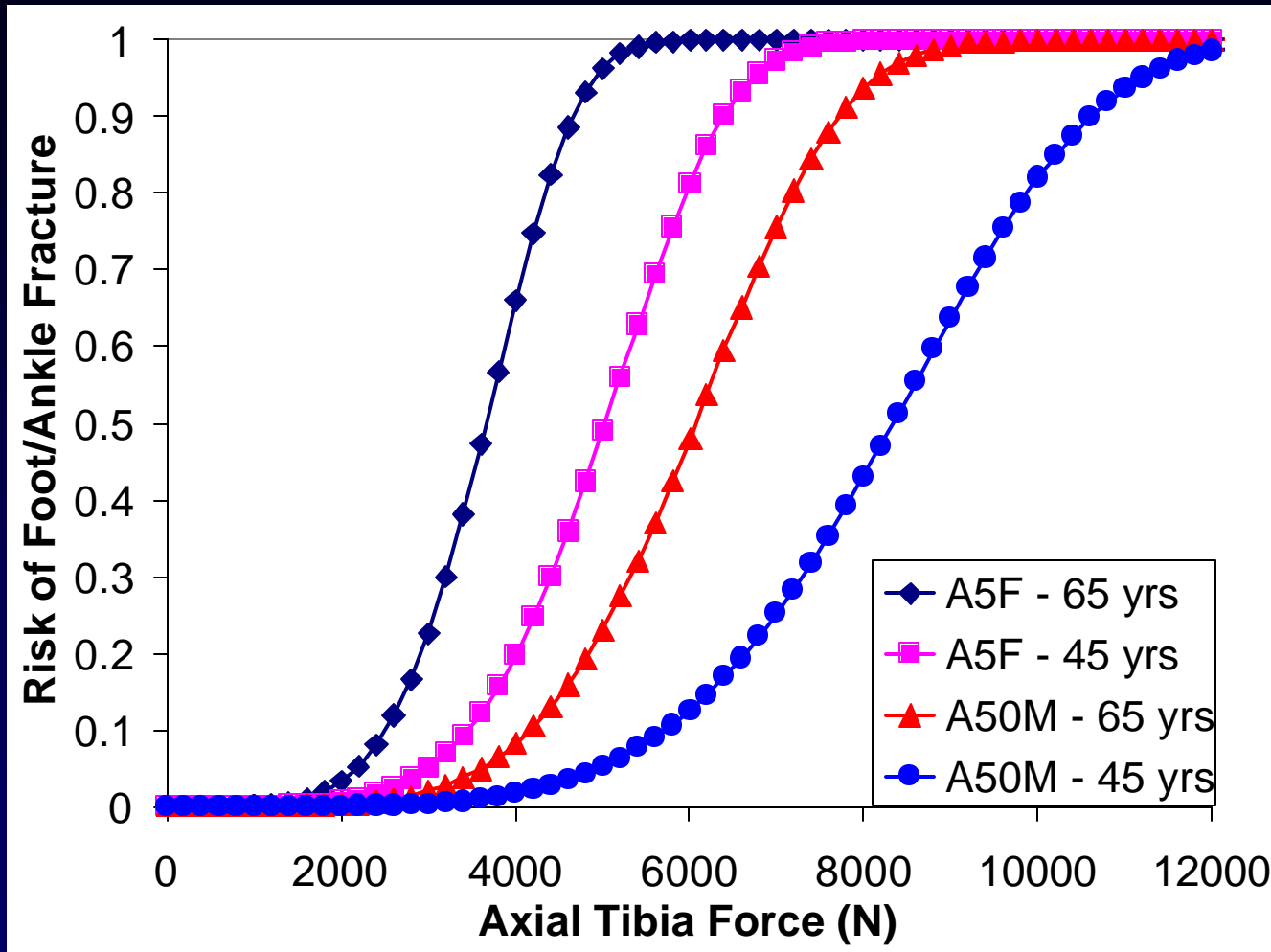


- Cortical Bone Content ↓
- Bone Density ↓
- Cartilage Ossification ↑
- Active Musculature ↓
- Pulmonary Stiffness ↑
- Stiffness Under Mechanical Loading?

Rib Fracture Tolerance vs. Age



How to Interpret? Injury Probability Functions (Funk 2001)

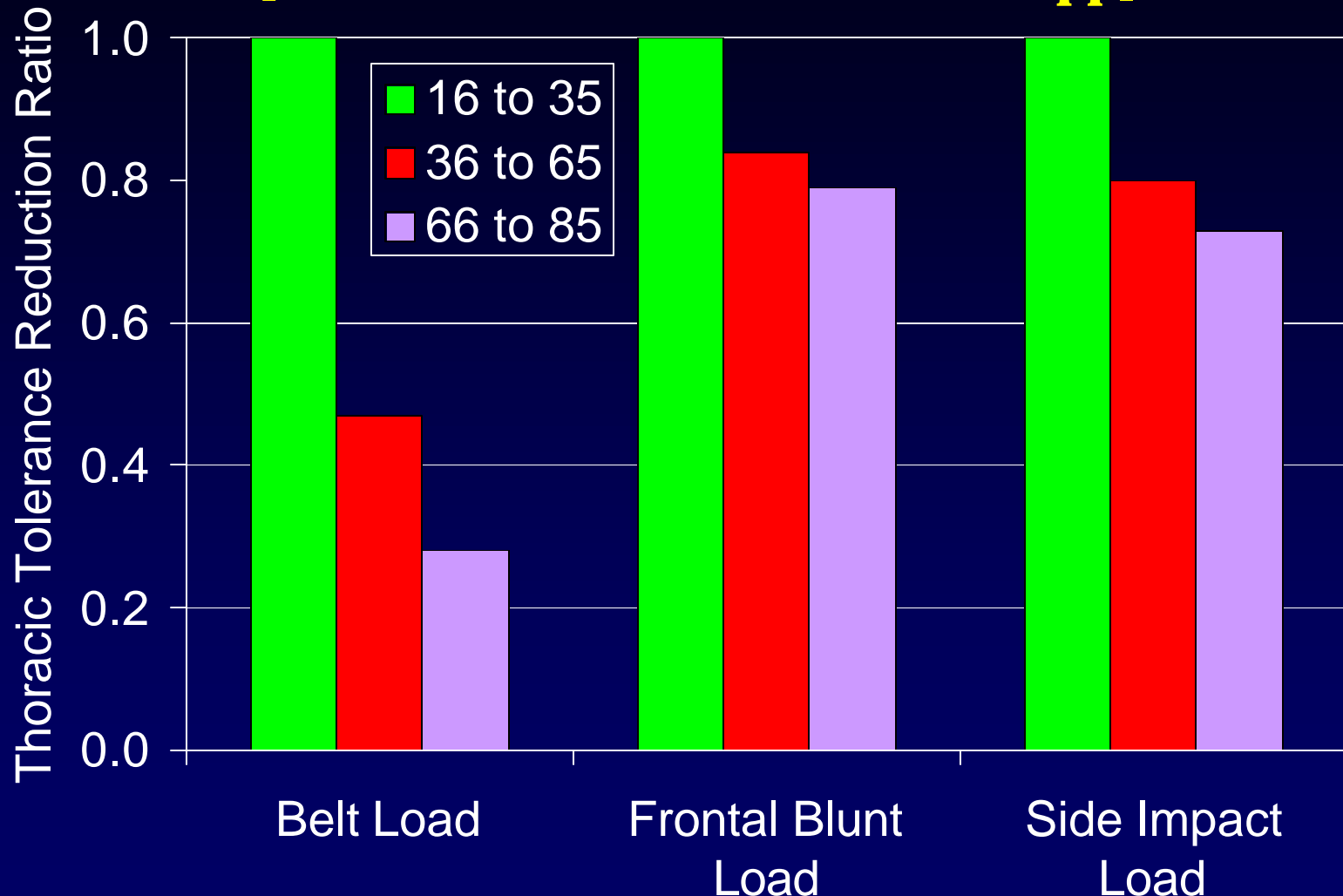


$$P(f) = \frac{1}{1 + \exp\left[-\left(4.99303 \cdot \ln f - 43.733733 - 0.963617 \cdot \text{gender} + 0.079284 \cdot \text{age} + 0.0004502 \cdot \text{ATF} - 0.0000001 \cdot \text{ATF}^2\right)\right]}$$

How to Interpret?

Reduction in Tolerance is $f(\text{Restraint Type})$

[Zhou, Rouhana, Melvin, 1996 Stapp]



Airbag Loading? Combined Belt/Airbag Loading?

CONCLUSIONS

- **Passive** Optimization
 - Population-based – Change in age small
- **Dynamic** Optimization
 - Optimized for Specific Occupant in Specific Collision
 - Additional Work Needed
 - Sensing
 - Dynamically Adjustable Restraints
 - Biomechanical Characterization of “Age”
 - Injury Tolerance, Constitutive Properties

Case Exemplar

Side Impact

- **39-year-old:**

**Female driver wearing
3-point seat belt
Air Bag deployed**

**V_1 : 1996 Toyota Camry
versus**

V_2 : Dump Truck

- **69-year-old:**

**Male driver wearing
3-point seat belt
Air Bag deployed**

**V_1 : 1995 Jaguar XJS
versus**

V_2 : 2000 Chevrolet Lumina

- **39-year-old:**

PDOF: 270°

?V: 38 km/h

CDC: 09LYAW4

Max crush: 49 cm @ C2

- **69-year-old:**

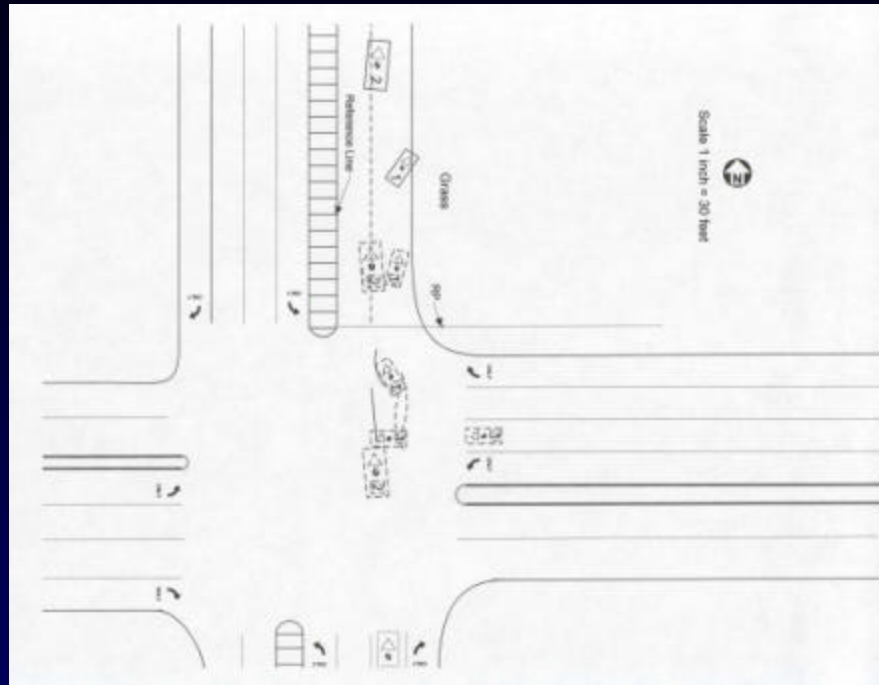
PDOF: 310°

?V: 8.6 km/h

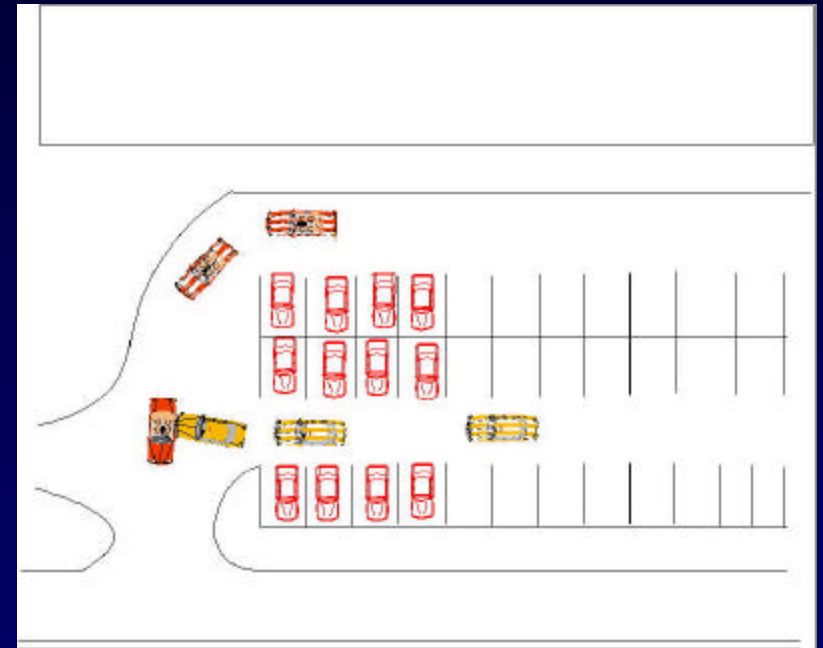
CDC Value: 10LPEW2

Max crush: 14 cm @ C3

39-year-old



69-year-old



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39-year-old



69-year-old



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Injuries

39-year-old

Injuries (ICD)	AIS Severity	Info Source	Aspect (R,L,bilat,etc)
Frontal lobe contusion x2 (851.00)	140614.3	CT	Posterior
Facial (ear) abrasions (910.0)	290202.1	Exam	Left
Tongue laceration (873.64)	243402.1	Exam	Under tongue
Upper extremity contusion (clavicle) (912.0)	790202.1	Exam	Left
Upper extremity (hand) abrasion (884.0)	790202.1	Exam	Right
Upper extremity (arm) contusion (912.0)	790402.1	Exam	Left
Lower extremity contusion (924.5)	890402.1	Exam	Bilateral
Lower extremity contusion (medial knee)	890402.1	Exam	Left

69-year-old

Injuries (ICD)	AIS Severity	Info Source	Aspect (R,L,bilat,etc)
5 th Rib fracture w PTX (807.01 & 860.0)	450214.3	X-ray	Left
Pulmonary contusion ((861.21)	441406.3	X-ray	Left
Laceration posterior calf – 5.5 cm (891.0)	890602.1	Exam	Left



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Case Summaries

- **39-year-old**

- Evaluation in the ER significant for abrasions and contusions to her face, upper and lower extremities.
- Head CT revealed 2 small (2 mm/3 mm) frontal lobe contusions.
- Discharged home on HD #2.
- Hospital Charge: \$9,868

- **69-year-old**

- Evaluation in the ER significant for 5 cm laceration of his left calf which was sutured in the ED.
- Chest x-ray revealed left-sided pneumothorax, fracture of the 5th rib on the left and left pulmonary contusion.
- Discharged home on HD # 3.
- Hospital Charge: \$3, 969

Case Exemplar Frontal Impact



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- **27-year-old:**

Male driver

Unrestrained

Air Bag deployed

1996 Ford Van E250

versus

Pole

- **57-year-old:**

Male driver

Unrestrained

Air Bag deployed

1997 Mazda Pick-up Truck

versus

Pole

- **27-year-old:**

PDOF: 0°

?V: 65 km/h

CDC: 12FCEW4

Max crush: 82 cm @ C3

- **57-year-old:**

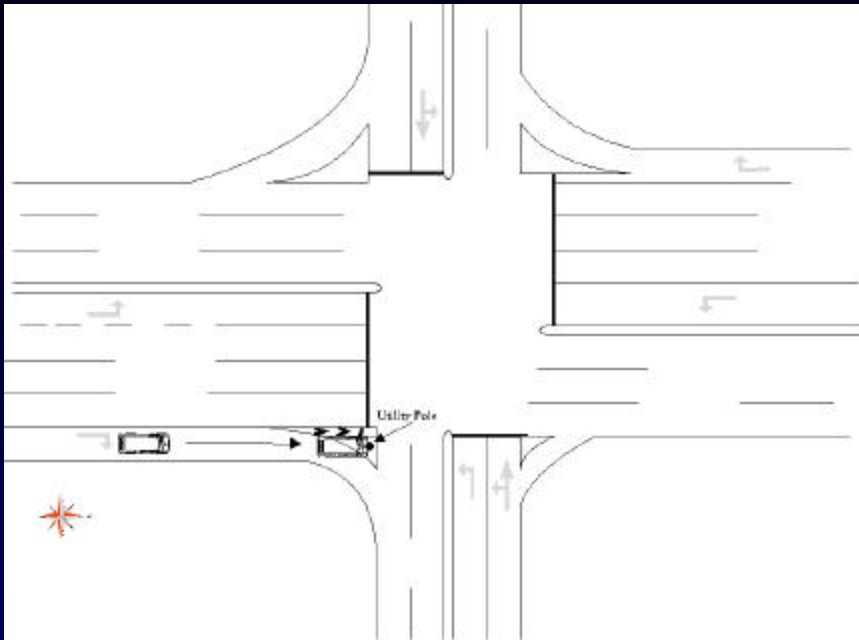
PDOF: 0°

?V: 39 km/h

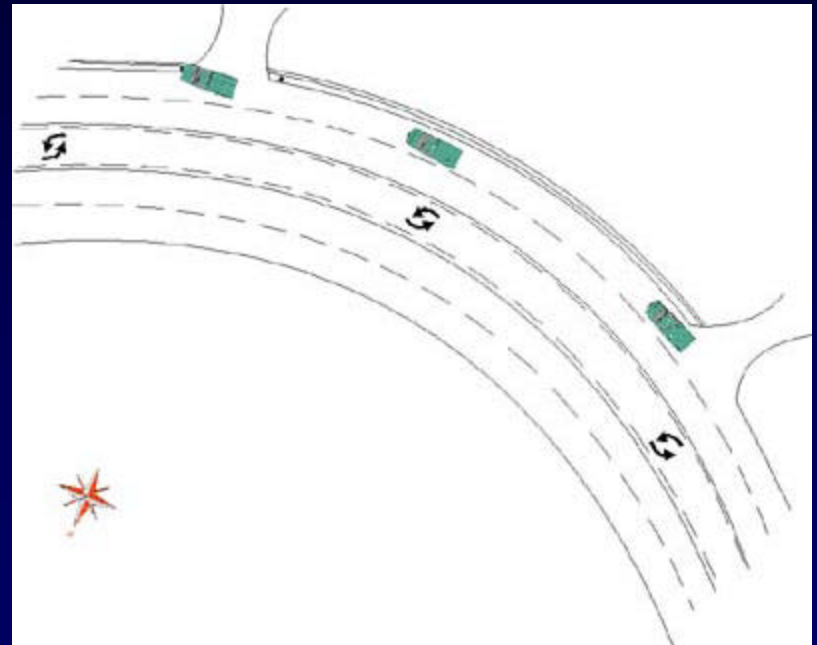
CDC Value: 12FREW3

Max crush: 44 cm @ C3

27-year-old



57-year-old

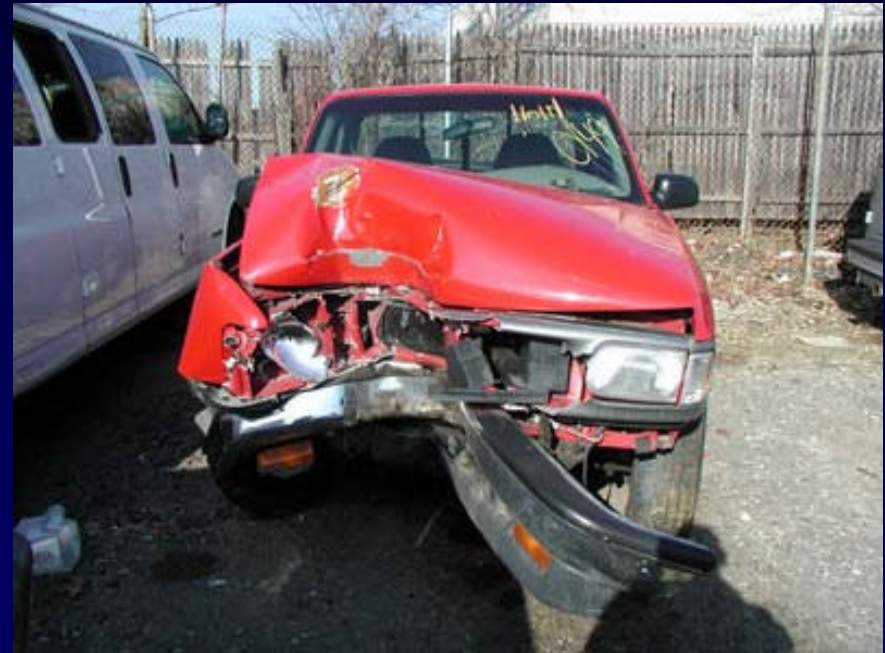


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27-year-old



57-year-old



Ford Inova Fairfax Hospital CIREN Center

Injuries

27-year-old

Injuries (ICD)	AIS Severity	Info Source	Aspect (R,L,bilat,etc)
Scalp abrasions (910.0)	190202.1	Exam	Center
Chest abrasion (911.0)	490402.1	Exam	Right
Arm laceration (884.0)	790602.1	Exam	Right
Hand abrasion (914.0)	790202.1	Exam	Left
Finger laceration (883.0)	790602.1	Exam	Right
Displaced acetabular fracture (808.0)	852604.3	CT	Right
Hip dislocation (835.00)	850614.2	CT	Right
Knee laceration (891.0)	890602.1	Exam	Left
Shin contusion (924.10)	890402.1	Exam	Left
Sciatic nerve contusion (956.0)	830602.2	CT	Whole
Lung contusion (861.21)	441402.3	CT	Bilateral

57-year-old

Injuries (ICD)	AIS Severity	Info Source	Aspect (R,L,bilat,etc)
Scalp abrasion (910.0)	190202.1	Exam	Central – hairline
Eyelid contusion (921.1)	290402.1	Exam	Right
Comminuted acetabular fracture (808.0)	852604.3	CT	Right
Hip dislocation (835.00)	850614.2	X-ray	Right
Knee contusion (924.11)	890402.1	Exam	Left



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Case Summaries

- **27-year-old**

- Evaluation in the ER significant for multiple abrasions and contusions.
- CT of the abdomen and pelvis identified a complex displaced right acetabular fracture and hip dislocation with displacement of the right superior ileum.
- HD #1 - ORIF of fracture
- Discharged home on hospital day # 4.
- Hospital Charge: \$19,619

- **57-year-old**

- Evaluation in the ER significant for a scalp abrasion, bruise on his right eyelid and bruise of his left knee.
- Radiologic examination identified a right comminuted fracture-dislocation of the hip and acetabulum.
- HD #2 - ORIF of fracture and removal of multiple loose fragments in the joint.
- Discharged home with home health care on HD # 29.
- Hospital Charge: \$46,699

Questions?